One Ecosystem 2: e14814
doi: 10.3897/oneeco.2.e14814

OPEN ACCESS

Review Article

Ecosystem services in Norway

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Academic editor: Miglena Zhiyanski

Received: 30 Jun 2017 | Accepted: 19 Sep 2017 | Published: 09 Oct 2017

Citation: Skre O (2017) Ecosystem services in Norway. One Ecosystem 2: e14814.
https://doi.org/10.3897/oneeco.2.e14814

Abstract

The present study is reviewing public reports and research articles in order to estimate and validate ecosystem services in Norway, and investigate conflicts between stakeholders representing different ecosystem services, by means of direct and indirect methods, for different main ecosystem categories,e.g. mountain ecosystems, forests,agricultural areas, freshwater ecosystems, marine ecosystems and urban areas. The ecosystem services (ES) are based on the three main well-known categories (providing, regulating and cultural services). The provisional services in Norway include some very important ES like fish & seafood production, timber and pulp products, bioenergy and genetic resources, while the regulating services in Norway include important services like flood and landslide protection, pest and disease control in forestry and farming, carbon fixation in forests and air quality regulation. These services are also influenced by climate, pollution, urbanization and invasive species. Finally, the cultural services, like recreation & ecotourism, health and well-being, knowledge & learning and spiritual enrichment, are included. The values of the ES are estimated and quantified by direct (market based) and indirect methods (e.g. preferences).

The relative importance of these ES is estimated by questionnaires and cost/benefit analysis, and administrative measures are suggested to compensate for threats and lack of sustainability. However, non-renewable resources like oil, gas and minerals are not included in the present overview. Among the ES in mountains, the value of outdoor activity as estimated from preference studies is totally dominating over the value of hunting and reindeer husbandry. Among the ES in forests the highest values are related to the health

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benefit from recreation, followed by the value of carbon fixation. The willingness to protect certain forests with high biodiversity is also high. Among ES from agricultural areas the provisional services (food and food processing) are dominating, while in freshwater ecosystems the value of wild salmon fishing measured by payment willingness, is dominating over the willingness to pay for improved water quality. Finally, the most important ES in Norway in monetary terms are found in marine ecosystems. Among the urban ES, the value of outdoor recreation and improved air quality represent the highest values. The most frequent conflicts in Norway are probably those dealing with energy production (windmills, hydropower production, oil drilling) and sea farming vs. biodiversity and recreation, between mass tourism and nature conservation and between sheep farming and conservation of big predators like wolf, bear, lynx and wolverine.

Keywords

Ecosystem services, validation, use and non-use values, conflicts between ES, employment, Climate, land-use, direct/indirect methods.

Introduction and objectives

Norway is located in the western part of the Scandinavian peninsula. It has a long coastline, reaching from the North Sea to the Arctic Ocean, and the name of the country actually means «The way to the North». Consequently, the Norwegians have always harvested ecosystem services from the Atlantic Ocean and the Barents Sea. The total area of Norway is 323 877 km^2 (Statens Kartverk 1996) where about one half of the area is above treeline and one third is forested (Table 8). In addition the Arctic Spitzbergen Islands are covering a land area of 62 700 km^2. The distance from the southern (58°N) to the northern end of Norway is 1 752 km, and the width varies from 6 to 430 km. Norway has a long coastline, including fjords (21 347 km) and islands (35 662 km), the total coastline is 53 070 km. Norway has a 2 542 km long border against Sweden, Finland and Russia. The mean July temperatures (1961-1990) vary from +9 to +16°C and the mean January temperature from -16 to +4°C. Precipitation varies from less than 300 mm in the most continental areas to more than 4 000 mm in the fjords along the coast. In Norway there is a total of 1 499 protected areas (1996) representing 6.4% of the total area, the two largest areas are on Spitzbergen Islands. Only 21 of these are more than 7 km^2, and most of them are national parks.

The total human population of Norway (2016) is 5.2 mill According to Statens Kartverk (1996) about 74% of the population in Norway are now living in urban areas, as result of the industrial and technological development. Only about 2.2% are employed in the primary sector (farming, fishing and forestry), while more than 20% are employed in the health & social service sector (SSB 2013). Other tertiary sectors like groceries, business & technical services and military & education is employing 10-15% each, while only about 10% are

employed in the secondary sector (industry, oil and mining) and about 6% in tourism (hotels and restaurants).

The Millennium Ecosystem Assessment (MEA) is a major assessment of the human impact on the environmenta, called for by the UN Secretary General Kofi Annan in 2000, lauched in 2001 and published in 2005. It popularized the term «ecosystem services», i.e. the benefits gained by humans from ecosystems. As a result of MEA, a number of studies have been made to identify ecosystem services in Europe and to quantify them by different direct and indirect methods in monetary terms. “The Economics of Ecosystems and Biodiversity” (TEEB 2009) was a follow-up of the Millennium Assessment to evaluate consequences of loss of biodiversity and ecosystem services. These reports have been further evaluated in public reports in Norway, e.g. NOU (2013). In addition, their importance may be estimated in terms of employment rates, published by the Norwegian Bureau of Statistics (SSB). Similar studies on Norwegian and European scale (e.g. Kyriazopoulos et al. 2017) have shown conflicts between stakeholders representing different ecosystem services (ES), and in the following, some examples of these conflicts are mentioned. The EU working group for “Mapping and Assessment of Ecosystems and their services” (Maes et al. (2013) has evaluated how biodiversity is influencing the socio-ecological processes in nature (see also Renterghem et al. 2013). Many of these ES are taken for granted because there are no reliable methods of quantitative evaluation.

Objectives

- To identify the most important ecosystem services in Norway
- To evaluate and quantify these ES in monetary terms by direct and indirect methods, and estimate their importance in terms of employment rates.
- To identify some important conflict areas between different ES, and suggestions for adaptive and/or response measures.
- To evaluate the sustainability of Norwegian ES

Background

In public reports, (e.g. NOU 2013) the total overall ecosystem services in Norway and their values are reviewed and evaluated for different main ecosystem categories, these are:

- Mountain ecosystems (Lindhjem and Magnussen 2012)
- Forests (Rolstad et al. 1998, Bryn 2008)
- Agricultural areas (Bjørdal 2007, Norderhaug et al. 2013)
- Freshwater ecosystems (e.g. Toivonen et al. 2004)
- Marine ecosysems (Nybø et al. 2012, Lindgaard and Henriksen 2011)
- Urban areas (Lindhjem and Sørheim 2012)

In the TEEB (2009) report the ecosystem services (ES) were generally derived from the basic life processes (supporting services) and separated into the three main well-known

categories (providing, regulating and cultural services). The provisional services in Norway include some very important ES like fish & seafood production (Olafsen et al. 2012), timber and pulp products (Kettunen et al. 2012), farm products (e.g. Asheim and Hegrenes 2006), bioenergy (Berglund et al. 2009) and genetic resources. The provisional services are generally strongly influenced by climate as well as land use changes and invasive species, that again may be indirectly influenced by climate change.

The regulating services in Norway include important services like flood and landslide protection, pest and disease control in forestry and farming, carbon fixation, pollination (Totland et al. 2013) and air and water quality regulation (Bolund and Hunhammar 1999, Tømmervik et al. 2013, Barton and Lindhjem 2013, Rusch 2012). These services are also influenced by climate, pollution, urbanization and invasive species. Finally, the cultural services, including important values and ES like recreation & ecotourism (Breivik et al. 2011, Kurtze et al. 2009), health and well-being (Haines-Young and Potschin 2013), knowledge & learning and spiritual enrichment (Hågvar and Berntsen 2001) have a large potential in Norway, where more than 50% of the area is above treeline. Many Norwegians, i.e. the Sami population in northern Norway, have a strong relation to the mountains and nature, but the value of the related ES have to be estimated by indirect methods and preference studies and questionnaires (Lindhjem and Magnussen 2012). Urban ES, mostly provisional and cultural, have been evaluated by e.g. Lindhjem and Sørheim (2012). These cultural ES are threatened, by land use changes caused by abandonment of mountain farming, and by noise and urbanization (Hågvar and Berntsen 2001, see Table 1 and Table 2).

Table 1.

Ecosystem services methods based on functions (Brouwer et al. 2013)

ES category	Market prices	Product function	costs	Revealed Prefer.	Given prefer.	comments
Provisonal						
Crops/timber	x	x				Most ES from agricultural ecosystems are capitalized in property prices, adjusted for investments in watering, draining etc. Bio-economic methods are used to estimate the value of the additional service.
Animals	x	x				See above comment
Wild plants	x					Market prices may be used as an estimate, when costs aare subtracted.
Fish product	x	x				Product function method is preferred, but market prices may also be used, when costs are subtracted.
Sea farming	x	x				See above comment
Genetic resources	x		X			Based on costs of licences and taxes, or additional costs of alternative genetic background.
Water supply	x	x	X			Market prices when available, or estimated prices.

Regulating						
Pollination		x	X			Bioeconomic modelling, that takes into account pollination. Alternativly costs of pollination technology may be used.
Climate regulation			X			Avoided damage costs is used.
Disease regulation		x	X			Based on costs of compensation
Erosion control		x	X			Avoided damage costs is used
Pollution control			X	x	X	Based on compensation costs (water purification)
Water flow regulation			X	x	X	Based on estimated avoided damage costs from flood and drought (payment willingness)
Envir. protection			X	x	X	Based on estimated avoided damage costs, or revealed or given preferances (payment willingness)
Cultural						
Recreation				x	X	Estimated travel costs and conditional evaluation
Aesthetics				x	X	Based on property prices and conditional evaluation

Table 2.

Examples of conflicts between ES in Norway

Benefitted ES	Threatened ES	Adaptive measure	References
Fish farming*1	Wild salmon population, fishing	Land based farms Closed systems	Armstrong et al. (2008)
Big predators (wolf, bear, lynx, wolverine)	Sheep farming, hunting	Compensation, controlled shooting	Asheim and Hegrenes (2006)
Hydropower, windmills	Biodiversity, tourism, recreation	Water flow control, Protection	Lindhjem and Magnussen (2012)
Flood protection	Biodiversity, wild salmon	Erosion control, flood tunnels	Sælthun et al. (2000)
Mass tourism	Nature conservation, biodiversity	Protection, traffic regulation	Lindhjem and Magnussen (2012)
Reindeer husbandry	Lichen growth, sheep farming	Less overgrazing, economical compensation	Tømmervik et al. (2009), Tømmervik et al. (2013)
Oil and mining	Fish resources, tourism	Protection	Klethagen (2005)
Forestry	Carbon fixation, (climate)	Sustainable forest management	Lindhjem and Magnussen (2012)
Urban development	Recreation	City planning	Lindhjem and Navrud (2011)

Methods

The evaluation procedure is based on a stepwise process, starting with the nature-based ES (Brink 2008) and ending up with economic validaton based on qualitative and quantitative criteria (Magnussen et al. 2010, TEEB 2008, Cardinale et al. 2012). The first step in the evaluation procedure is to recognize and understand the ES by means of scientific and traditional knowledge (Barton et al. 2012). Then the values of the ES are estimated and quantified by direct (market based) and indirect methods (e.g. preferences). The relative importance of these ES are then estimated by questionnaires and cost/benefit analysis, and finally administrative measures are suggested to compensate for threats and lack of sustainability. In order to achieve an overview of the total socio-economic values, the ES should not only be estimated as “use values” (direct or indirect), but also by “non-use values”, that are not involving the use of ES, but rather the wish of preserving biodiversity and ES to-day and in the future (Pagiola et al. 2004, De Groot et al. 2010). The direct use values, that are evaluated by market based methods, may be further subdivided into consumption (e.g. food, fiber) and non-consumption (e.g. recreation, knowledge), while indirect methods include regulating services like pollination and water control. In addition optional values include future use of known or unknown ES. On the other hand, non-use values include three main categories that may overlap, i.e. existence values, or pleasure of knowing the existence of some ES, bequest values and altruistic values, i.e. the pleasure of knowing that future generations or people in general will have access to the ES (TEEB 2009). The value of indirect and optional as well as non-use ES is usually estimated by preference studies, where respondents are quantifying their willingness to pay the extra cost of the actual ES. The three main categories may also be classified according to Chee (2004) and Hanley and Barbier (2009) in terms of market type (actual, parallel or hypothetical). Because of the high costs related to estimation of ecosystem values, two methods have been developed (Navrud 2004) for transfer from other studies, by simple or adjusted unit transfer, or by transfer of payment willingness (benefit function) or combined function transfer (meta-analysis).

The evaluation methods mentioned above used for different ES categories in Norway may be summarized in Table 1 (Brouwer et al. 2013) where provisional services and certain regulating services (carbon fixation, disease control, erosion control and pollination) may be evaluated by market based methods, while other regulating services like pollution control, water flow regulation etc. are evaluated by estimated avoided damage costs or compensation costs. Finally, cultural values like recreation can’t be estimated by actual market based methods but only by preferences based on travel costs or property prices.

Results and discussion

From other studies, e.g. of treeline ecosystems in Europe, information has been obtained about benefits and threats to the ecosystem by questionnaire technique (Kyriazopoulos et al. 2017). The stakeholders that were most beneficial to the treeline ecosystem in 20

selected areas are recreationists, scientists & students and bird watchers. On the opposite side of the diagram are found mining companies, windmills and snowmobile owners, army, hydropower companies and forestry. Ski resorts and downhill skiers are also evaluated as a net threat to the treeline ecosystem. Generally, all ES are considered as benefits to some stakeholders and as threats to others, and in many cases conflicts may develop between stakeholders about the prevailing ES of an area or ecosystem. The most frequent conflicts in Norway as seen from Table 2, are probably those dealing with energy production (windmills, hydropower production, oil drilling) vs. biodiversity and recreation, between mass tourism and nature conservation, between sheep farming and conservation of big predators like wolf, bear, lynx and wolverine, and between reindeer husbandry and sustainability (e.g. lichen growth). There is also a constant debate in Norway between foresters and environmentalists about how to use the forests in order to reduce the carbon output (carbon fixation vs. bioenergy). Recently also fish farming has become a major threat against the wild salmon population.

Population and employment

In Norway 74% of the population are now living in urban areas, as result of the industrial and technological development, while only 2.2% are employed in the primary sector (farming, fishing and forestry). The highest employment rates are found in the health & social service, and this sector has increased recently due to increasing age of the population (SSB 2013). Other tertiary sectors like groceries, business & technical services and military & education is employing 10-15% each, while only 10.8% are employed in the secondary sector (industry, oil and mining), 5.5% in tourism (hotels & restaurants) and 7.0% in construction. It is interesting to compare different counties or regions in Norway. Finnmark in northern Norway shows a relatively high employment rate in the primary sector (fishing) and low rates in industry and business. Similarly, the county of Hedmark in southeastern Norway also has a high employment in the primary sector (farming). On the other hand, Hordaland county in western Norway with the second largest city, Bergen, has relatively high employment rates in industry and corresponding low rates in the primary sector, although the fish farming industry is strong.

Evaluation of ES in Norway (Table 3-7)

In the following, the direct and indirect methods described above, have been used to estimate and quantify in monetary terms the ecosystem services in Norway. Among the ES in mountains (Table 3), the value of outdoor activity as estimated from preference studies is totally dominating over the value of hunting and reindeer husbandry. Among the ES in forests (Table 4) the highest values are related to the health benefit from recreation, followed by the value of carbon fixation. The willingness to protect certain forests with high biodiversity is also high. Among ES from agricultural areas (Table 5) the provisional services (food and food processing) are dominating, while in freshwater ecosystems (Table 6) the value of wild salmon fishing measured by payment willingness, is dominating over

the willingness to pay for improved water quality. Finally, the absolutely highest ranking ES in Norway are found in marine ecosystems (Table 7). The provisional services (fish production) are dominating among the “use values” but tourism and the estimated carbon fixation in oceans outside the Norwegian coast is also high. According to Nellemann et al. (2001) 55% of the fixed carbon is stored in the oceans. In addition to the use values of 10-15 000 MEUR the amount of non-use values, like land based sea farming and restoration of damaged coral reefs are of the same order of magnitude. According to a large number of preference studies in Norway, this is part of a general trend, i.e. non-use values, mostly existence values, are of the same order than use values. Finally, a large part of the use values is “optional values” representing opportunities for later use (Magnussen et al. 1995).

Table 3.

Ecosystem services in mountains*2

ES category	**Ecosystem service**	**Estimated value** (mill NOK/yr)	**Comments**	**References**
Provisional	Net income from grouse hunting	16	Hunting licences, cabin renting and guiding	Andersen et al. (2010)
Regulating & cultural	Hunting preferences	459-648	Hunting licence, cabin, weapon and ammunition	Andersen et al. (2009), Skonhoft and Gudding (2010)
Provisional	Meat value of wild reindeer hunting	13	Based on a price of 70 NOK/kg	Bråtå et al. (2010), Nellemann et al. (2001)
Provisional	Meat value of domestic reindeer	141	Based on a price of 67.40 NOK/kg	Tømmervik et al. (2013)
	Total	**600-800 (70-90 MEUR)**		
Regulating & cultural*2	Outdoor activity	7 500	20% of total	Lindhjem and Magnussen (2012)

Table 4.

Ecosystem services in forests

ES category	**Ecosystem service**	**Estimated value** (mill NOK/yr)	**Comment**	**Reference**
Provisional	Carbon fixation	7 500-9 000	25-30 mill t CO2/yr and 300 NOK/t	Lindhjem and Magnussen (2012)
Provisional	Forest products	6 200	Timber, fuel, hunting, growth in biomass	SSB (2012) NOU (2013) *8
Provisional	Supplementary services	726	Renting income, fishing & hunting licences	Lindhjem and Magnussen (2012)

Regulating	Estimated value of recreation	10 000-20 000	Health benefit and payment willingness	Lindhjem and Magnussen (2012)
Provisonal	Damages from moose	300-400	Grazing and collision	Olaussen and Skonhoft (2011)
Cultural	Forest management	3 600	Willingness 1 200 NOK/ person in cities	Lindhjem (2007)
Cultural	Forest protection from 1.4 to 2.8 %	3 000-4 000	Willingness 1 100 - 1 500 NOK/ person in cities	Lindhjem and Navrud (2011)
	Total	**31 000-44 000 (=3 400-5 000 MEUR)**		

Table 5.

Ecosystem services in agricultural areas and lowlands

ES category	**Ecosystem service**	**Estimated value** (mill NOK/yr)	**Comments**	**References**
Provisional	Income from plant production	7 100	Grain, potatoes, oil & horticulture	SSB (2012)
Provisional	Income from animal production	18 700	Milk, egg and meat production	SSB (2012)
Provisional	Food processing	20 000	Dairy and meat products	SSB (2012), SSB (2013)
Regulating	Value of outdoor animal grazing	800	Based on number of animals and uptake of food	Asheim and Hegrenes (2006)
Regulating	Pollination and honey production	250	Estimated from Sweden	SSB (2012)
	Total	**46 850 (= 5 200 MEUR)**		

Table 6.

Ecosystem services in freshwater

ES category	**Ecosystem service**	**Estimated value** (mill NOK/yr)	**Comment**	**Reference**
Regulating	Improved water quality for recreation	1 800-3 500	Payment willingness	Magnussen (1992)
Regulating	Improved water quality (estimate)	1 600	Payment willingness	Magnussen et al. (1995)
Regulating	Flood and erosion control	50-100	Government funding	Sælthun et al. (2000)
Regulating & cultural	Recreation value of fishing	500-1 500	Conditional value vs. travel value	Navrud (2004)

Regulating	Recreation value of salmon fishing	30 000	Payment willingness	Toivonen et al. (2004)
Provisioning	Salmon fishing (estimate)	260	Estimated from Trondheim area	Kjelden et al. (2012)
Regulating	Calcium treatment	104-128	Government funding	DN*3 2011
	Total	**38 800-50 600 (=4 300-5 600 MEUR)**		

Table 7.

Ecosystem services in coastal areas and oceans

ES category	**Ecosystem service**	**Estimated value** (mill NOK/yr)	**Comment**	**Reference**
Regulating	Improved water quality	100	Conditional value of sedimentation	Barton et al. (2012)
Regulating	Preventing oil spills	150	Payment willingness	Klethagen (2005)
Regulating	CO2 fixation in ocean	20 000-40 000	300-800 kr/t	Magnussen et al. (2010)
Provisional	Fish production	24 000	Included fish processing	SSB (2012)
Provisional	Sea farming production	30 000	Included processing	Henriksen et al. (2012)
Provisional	Values related to sea farming	20 000	Marketing value of service	Henriksen et al. (2012)
Regulating	Recreation fishing	5 200	Payment willingness	Magnussen et al. (2010)
Provisional & cultural	Tourism	12 500	Marketing values	Magnussen et al. (2010)
Regulating*4	Environmental protection	1-15 800	Land based sea farming	Armstrong et al. (2008)
Regulating*4	Restoration of coral reefs	112 000	KO-values	Armstrong et al. (2008)
	Total value	**110 000-132 000 (=12 000-14 000 MEUR)**		

In the summary table (Table 8) the urban ES are also included (Lindhjem and Sørheim 2012), with a total estimated value of 14 300 NOK (1 600 MEUR). The value of outdoor recreation and improved air quality represent the highest values in urban areas. The ES per total area is highest in urban, freshwater and agricultural areas and lowest in mountain ecosystem. The marine ES with a total value of 121 000 NOK (16 000 MEUR) are distributed over a large part of the Atlantic Ocean. However, many ES may be underestimated because of lack of appropriate methods, i.e. those related to mountain ecosystems. It should be emphasized that in the following, only ecosystem services that are linked to renewable resources, are included (Table 8) with a total estimated value of 271 650 mill. NOK. In addition to these, the income from gas and oil activity is estimated to

128 000 mill. NOK (2016), and income from mining to 8 200 mill. NOK. Hence, the income from fishing and fish farming is already of the same order of magnitude as the oil and gas income (121 000 mill. NOK).

Table 8.

Summary of ecosystem services in Norway compared with total area

Ecosystem category	Area km^2	Area % of total	ES (mean values) NOK
Mountains	165 000	50	8 000*5
Forests	117 000	36	37 500
Agricultural areas	9 000	3	46 850
Urban areas	3 000	1	14 300*7
Marine values/sea islands	16 000	6*6	121 000
Freshwater	14 000	4	44 000
Total	**324 000**	**100**	**271 650**

Conclusions

The present study shows that in terms of employment rates the most important ES seem to be associated with the secondary sector (food and forest production), urban recreation and tourism. In monetary terms, however, marine ES represent the highest values followed by farming and forestry, urban recreation and freshwater ES. The ES related to mountains are ranking relatively low, but are probably underestimated because of lack of reliable methods for valuation. Non-use values that are difficult to measure in monetary terms, seem to be of equal importance as use values.

Main conflict areas are between fish farming and wild salmon fishing, between energy production and recreation, between sheep farming and nature conservation and between forestry and carbon fixation. In the future, when a strong increase in fish farming products is expected, the conflicts related to this sector are expected to be a serious problem, and the solution may be to keep the fish farms in closed systems with waste control.

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Endnotes

*1 Fish farming is dependent on:

- temperature and light
- water quality
- pollution and disease control
- control of genetic resources
- sustainable management of marine resources

*2 Ecosystem services from outdoor activity (total) is estimated from preference studies to beof the order of 25-50 000 mill. NOK. In the present overview this amount is distributed evenly between the categories mountains, forests, freshwater, coastal areas and urban areas. However, in the categories forests, freshwater and coastal areas these values are already accounted for by other studies.

*3 Norwegian Directorate for Nature Management

*4 Not included in the total budget

*5 7 500 (outdoor activity) + 500 (hunting and reindeer husbandry)

*6 Only islands

*7 7 500 (outdoor activity) + 400 (health benefit) + 6 400 (50% NOx reduction)

*8 Norges Offentlige Utredninger (Public Reports of Norway)